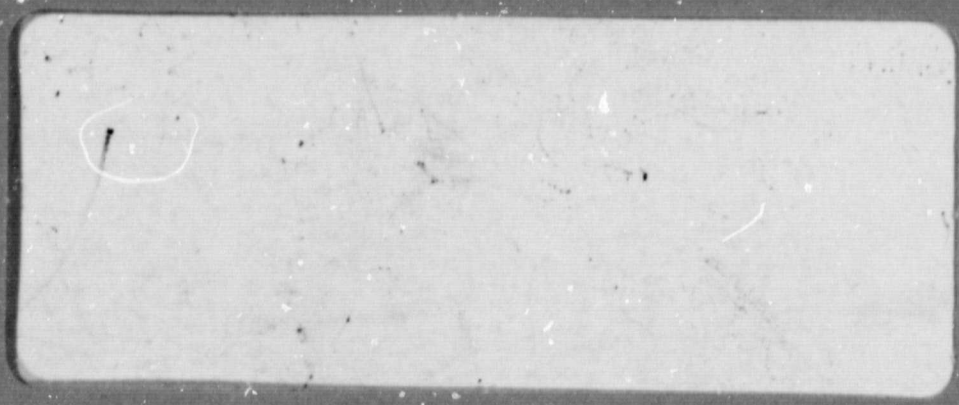


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THE AEROSPACE CORPORATION

Final Report

Modelling of Auroral Electrodynamical Processes:

Magnetosphere to Mesosphere.

NASA Solar-Terrestrial Theory Contract NASW-3434

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### Abstract

An overview of a three-year term of researches on auroral electrodynamical coupling between the magnetosphere and ionosphere-atmosphere is given. This final report succinctly summarizes the activities of the research team, which is comprised of scientists from The Aerospace Corporation, University of California at Los Angeles and Jet Propulsion Laboratory and is supported by the NASA Solar-Terrestrial Theory Program contract NASW-3434. It is shown that the interdisciplinary team has successfully focused its work upon building the basic elements in unifying local plasma theories of auroral magnetosphere-ionosphere coupling into a global one. The global goal of unification is being pursued in the new term of research.

## I. INTRODUCTION

This is the final report of the first three-year term of the Solar Terrestrial Theory Grant entitled "Modelling of Auroral Electrodynamical Processes: Magnetosphere to Mesosphere."

In this report we shall attempt to give an overview of the direction and execution of researches performed under the contract. As the result of cooperative theoretical and observational researches, such as the present effort, scientific understanding of the auroral coupling between the magnetosphere and atmosphere has grown by leaps and bounds in the last five or six years. A comprehensive assessment of this particular progress is documented in the magnetosphere-ionosphere working group report of the recent Solar-Terrestrial Physics Workshop at Coolfont, W. Va., and sponsored by NASA and NSF. The research program performed under the present contract is an integral part of the auroral work assessed in the above report; thus, the main viewpoint in this final report will be forward-looking, emphasizing what is ahead for auroral physics and how it fits into the global scheme of quantitative solar-terrestrial theory.

We shall show that the results of our researches under this contract are partial elements, which, together with results of auroral theoretical and observational researches of other groups, form a basis for unifying various theories of auroral magnetosphere-atmosphere coupling into a global scale theory. The unifying thread is the approach that we have used in our researches: global-scale plasma kinetic theory in which the global-scale morphology of magnetic and electric fields is the major driver of microscopic kinetic plasma phenomena which form the final link in the coupling. We have

successfully applied this point of view to formation of the evening discrete arc, to the morningside arc system and to polar cap arcs. With further observational support from Dynamic Explorer and S3-3 results, we are now poised to attack the unifying problem of global arc formation theory. Indeed, as we are preparing this report, theoretical clarification of the relationship between polar cap arcs (including the recently discovered  $\theta$ -auroral configuration) and oval arcs based on this point of view is at hand [Workshop on Polar Cap Processes, AFGL, Bedford, MA, 1983].

Aside from the forward-looking emphasis on unification of global auroral magnetosphere-atmosphere coupling, a second characteristic of our researches under this contract is the emphasis on theory-data verifications and theoretical guidance for accompanying observational programs. The close relationship of theoretical guidance and observational verification is particularly well-documented in S3-3 data analysis, from which an important portion of the advances in auroral physics of the past 5-6 years has originated. An important achievement of our program is to carry forward this symbiotic relationship to understanding the kinetic plasma convection phenomena at equatorial regions of auroral field lines as measured by the SCATHA satellite. Similarly, complex computation programs on auroral particle interactions with the atmosphere patiently built up under this contract will find their full verification in the theory of auroral emissions in the UV to X-ray range, which will be emphasized in future programs such as OPEN. The same can also be expected in the elucidation of dynamical atmospheric motions associated with auroral substorms.

## II. ACCOMPLISHMENTS OF PROGRAM

Since commencement of the present contract, in October 1980, researches undertaken in our program have progressed according to the plan envisioned in the initial proposal. A list of publications and presentations with acknowledged support, fully or partially, by the Solar-Terrestrial Theory Program is given in Appendix I.

In the initial proposal, the program plan was to investigate a number of separate, but coherently related, topics by appropriate team members. At a mature stage of the investigation, these separate projects are to form the foundation from which a global auroral magnetosphere-ionosphere-atmosphere coupling model is to be constructed. For a summary of the physical basis for this staged development of the coupling model, the reader is referred to Section III of a review of the present status of auroral plasma research [Chiu et al., 1983a]. This review also summarizes the cross-fertilization and cooperation with auroral experimenters, which characterize our work. Thus, a tangible accomplishment of our program is the guidance that our theoretical program provides to experimenters concerning the important physical issues in data analyses and plasma observations. These include developments in the observational study of auroral electric potential structure, ion conics, plasma injection into the auroral region and auroral return currents.

In the past three years, several general areas pertaining to auroral magnetosphere-ionosphere-atmosphere coupling and forming separate elements of the global theory have been under investigation. The accomplishments achieved in these areas are briefly reviewed below in terms of progress toward our proposed goal of developing a model of global magnetosphere-ionosphere-atmosphere coupling.



### A. Electric Potential Structure in the Evening Sector

A key element of auroral magnetosphere-ionosphere coupling is the understanding of discrete arc formation in the evening sector. The first efforts in explaining auroral  $E_{\parallel}$  naturally concerned themselves with a local point of view: a single auroral field line, with boundary conditions at the equator and ionosphere [Chiu and Schulz, J. Geophys. Res., 83, 629, 1978]. This approach led to a fruitful understanding of how magnetic-mirror forces set up  $E_{\parallel}$  fields and roughly what strength these fields would have, but was not in principle capable of precise determination of auroral potential drops.

It soon became clear that the ionosphere played an all-important role in coupling neighboring field lines [Chiu and Cornwall, 1980; Lyons, J. Geophys. Res., 86, 17, 1980], which thus forced an enlargement of the purely local point of view. An extremely valuable result of this later work was an understanding of what we will call the outer (or largest) scale of inverted-V's, that is, their latitudinal width. This width  $\Lambda$  is equal to  $(\Sigma_p/Q)^{1/2}$ , where  $\Sigma_p$  is the auroral height-integrated Pedersen conductivity (as enhanced by electron precipitation) and  $Q \sim n e^2/m_e \bar{v}_e$  where  $n$  is the density and  $\bar{v}_e$  a typical velocity of plasma-sheet electrons which will be accelerated by the auroral potential drop. It turns out that  $\Lambda \sim 50 - 100$  km, in excellent agreement with experimental data.

This outer scale links the electric fields along  $\vec{B}$  with those across  $\vec{B}$ , and thus the global morphology of electric and magnetic fields [Lyons, J. Geophys. Res., 86, 17, 1980], according to a formula [Chiu et al., 1981] which we quote only in a highly-simplified form:

$$\Delta\phi = - \int_0^{\infty} dx e^{-x/\Lambda} E_{\perp}(x) \quad (1)$$

where  $x$  is N-S distance in the ionosphere, and  $E_{\perp}$  is the equatorial perpendicular field mapped to the ionosphere as if there was no parallel potential drop. The left hand side,  $\Delta\phi$ , is the (positive) potential drop between ionosphere and equator along the center ( $x=0$ ) of the inverted-V, and in this simple form we take it that  $E_{\perp}(x) = -E_{\perp}(-x)$ , that is, there is a reversal of the perpendicular convection field about the central auroral field line.

Thus, at one stroke, we are able to bridge the gap between local one- and two-dimensional theories to global two-dimensional theories in which the global  $E_{\perp}$  structure is important.

Observational verification of the various aspects of (1) indicates to us that our basic kinetic approach to evening auroral magnetosphere-ionosphere coupling is on the right track. Meanwhile, other key elements toward a comprehensive model of the evening electric potential structure have been investigated. These are: (1) elucidation of the relationship between observed adiabatic plasma motion and plasma turbulence effects, and (2) solution of Poisson's equation for the two-dimensional structure of  $\phi$ , which is considerably more complicated than the quantity  $\Delta\phi$ , the ionosphere-to-magnetosphere potential drop. Researches on both areas are progressing according to schedule and interim results have been, or are being, published. Cornwall and Chiu [1982], in particular, have shown that plasma turbulence can have very important time-dependent effects on the global structure of the coupling. In this work electrostatic ion cyclotron waves, driven by an electron beam, heat ions in  $T_{\perp}$  thus reducing the magnetic-mirror forces which set up the  $E_{\parallel}$  which drives the electron beam. The result can be a steady state accommodating of both adiabatic and turbulent effects, as observed, but it can also be a relaxation oscillator whose longer time period

is  $\sim 10$  sec, identified with an ion-transit time scale.

Preliminary results of a detailed two-dimensional auroral potential structure model, involving complex equilibria of many species of auroral plasma and static electrostatic fields, have also been communicated to the space plasma physics community [e.g. presentation by Newman et al., 1982]. A comprehensive paper on this topic is currently in preparation [Newman et al., 1983]. A significant theoretical result of this complex model is the proposed description of the auroral return current as driven by a downward parallel potential drop of  $\sim 100$  eV thus driving ionospheric electrons upward to balance the precipitation of magnetospheric electrons in the auroral arc. This proposal, originally advanced in Chiu, Newman and Cornwall (1981), has turned out to be prophetic in that evidence of upward electron beams of similar energy has recently been discovered in Dynamic Explorer results [Burch et al., Geophys. Res. Lett., 10, 753, 1983] and in S3-3 data. The S3-3 data further indicates [Gorney, Croley and Chiu, 1983] that this parallel electric field plays an important role in trapping ionospheric ions, thus allowing them to be heated to high energies to form conics. This may be the initial step in arriving at the solution to the long standing puzzle of conic formation.

#### B. Morningside and Dayside Auroras

To construct a global model of auroral magnetosphere-ionosphere-atmosphere coupling, an understanding of aurora formation mechanisms in the morning and dayside sectors are just as important as that of the evening sector, even though the current theoretical effort in the scientific community is concentrated on the parallel electric field of the evening sector. Although observations of auroral plasmas have long indicated absence of electric acceleration in the morningside auroras, a systematic attack on their forma-

tion mechanism has not been attempted. By invoking recently-analyzed results of plasma observations on S3-3 and SCATHA satellites, we have constructed a theory of morningside arc systems based on the modulation of diffuse auroral electron precipitation by the mirror instability driven by auroral ions [Chiu et al., 1983b]. An especially interesting feature of this theory, in agreement with SCATHA plasma observations, is that the ionospheric ions ( $O^+$ ) accelerated upward from the evening discrete arc and convected to the diffuse aurora region is a key element in the stabilization of the mirror instability in the evening sector; thus, again demonstrating the necessity of considering auroral magnetosphere-ionosphere coupling in its global setting.

### C. Polar Cap Auroras

Correlation studies of polar cap arcs and low-altitude polar cap convection patterns ( $E_{\perp}$ ) have indicated a relationship between these integral elements of auroral magnetosphere-ionosphere coupling to the pattern of northward interplanetary magnetic fields. Recently, the importance of such correlative studies has been brought into focus by the new discovery of the  $\theta$ -aurora [Frank et al., Geophys. Rev. Lett., 9, 1001, 1982] for which the low-altitude electron signatures were noted to be that of the inverted-V.

From the perspective of global aurora formation theory, the uniqueness and, at the same time, similarity of the polar cap aurora with other auroras pose a major question in auroral physics: Are we witnessing a new type of aurora formation process entirely distinct from the evening discrete arc, with  $E_{\parallel}$  signature, and from the morningside arc system, without  $E_{\parallel}$  signature [Chiu et al., 1983a]?

Chiu and Gorney [1983] demonstrated that polar cap arcs are identical to oval discrete arcs in electric field and plasma signatures. Evidently, intrusions or presence of hot plasma from the plasmashet and/or magnetosheath produces discrete arcs of whatever configuration if the proper  $E_{\perp}$  signature indicating upward field-aligned current is also present. In short, arc formation of whatever configuration takes place if (1) is satisfied. Thus, the combined consequence of (1) and the plasma intrusion hypothesis is that arcs formed by parallel potential drops (oval and polar cap discrete arcs) of whatever configuration have their origin in the concentrated  $E_{\perp}$  of the boundary layer, which, in whatever configuration, is also the source of the hot plasma being precipitated by the parallel potential drop. Moreover, this conclusion, though illustrated with the kinetic theory of arc formation above, has been demonstrated with plasma and electric field data and is not limited to any one particular theory.

The theme of global unification of arc formation theory is once again demonstrated. It now remains for our researches to advance the hypothesis by examining how auroral plasmas come to be present at auroral field lines and with what kinetic signatures.

#### D. Auroral Plasma Formation

In the past few years, researches in magnetosphere-ionosphere coupling have focused considerable attention upon how auroral plasmas precipitate to form the optical signature. However, underlying the precipitation mechanisms, a major question of kinetic aurora theory needs to be addressed in detail: From where and how does the auroral plasma acquire its kinetic characteristics such as temperature and pitch angle distribution? In short, how is the auroral plasma formed?

By using the properties of the exact Green's function solution of the collisionless time-dependent Boltzmann equation, Chiu and Kishi (1983) have been able to construct a time-dependent model of auroral plasma formation by global time-dependent convection electric fields in dipolar magnetic geometry. The significant result of this development is that two-dimensional  $(v_{\parallel}, v_{\perp})$  distribution functions can now be mapped backward and forward in space-time in an economical invariant-preserving manner. Since distribution function information in the equatorial auroral region is now made available in recent satellite particle experiments such as those onboard SCATHA and GEOS, we expect that a natural consequence of our development will be the ability to interpret the satellite distribution function data in terms of sources and fields; whereas, previously, one is restricted to segmented tests of the convection model such as energy-time dispersion in isolation of important parameters such as pitch-angle distribution.

Because of the large variety of theoretical and observational application of our model, we have restricted the presentation in the above initial work to the time-dependent effects upon the convection of electrons. Even so, we have demonstrated that many of the interesting features of electron distribution functions seen for the first time recently can be schematically understood in terms of a very simple time-dependent convection model. We have shown examples that bear on the formation of square-box gradients and field-aligned distributions, on injection fronts and on inverse dispersion signatures. The principles of detailed data verification of theory, using SCATHA data, will be published in cooperation with experimenters.

### E. Electrodynamic Coupling with the Thermosphere

The modeling of the dynamical response of the high latitude neutral thermosphere to sudden deposition of auroral energy, using an idealized high-resolution spectral model, is advancing according to the plan stated in the initial proposal. The model [Walterscheid and Boucher, 1982] treats disturbances of the thermosphere due either to the deposition of energy by a momentum source (such as ion drag) or a heat source (such as Joule dissipation or particle precipitation). The model describes two-dimensional dissipationless motion on a basic state which is isothermal and at rest. The model differs from steady-state models (such as employed by investigators at Utah State University) in that it is time dependent, and differs from previous idealized time-dependent models in that it includes the effects of the earth's rotation. Rotation permits the existence of inertial oscillations and geostrophically balanced motion. The model is appropriate for studying the transient response of the lower thermosphere to typical auroral and sub-auroral scale disturbances. These scales may be considerably smaller than those of present global models such as at NCAR and GSFC. Initial calculations were performed for selected vertical wave numbers in order to study the dependence of the dynamical response on the vertical scale of the motion. Model results indicate that: (1) for an ion drag source a strong residual geostrophic flow is favored by forcing in a deep layer, whereas a strong residual inertial oscillation is favored by forcing in a shallow layer, (2) for a Joule heating source a strong residual geostrophic flow and inertial oscillation are both favored by forcing in a shallow layer, and (3) the ion drag source may excite gravity waves through the action of the Coriolis force in deforming pressure surfaces across the initial flow, the effect being more pronounced for forcing

in a shallow layer. We have extended our model to consider contributions from a continuous spectrum of vertical scales of motion excited by an initial disturbance of a prescribed width and depth. The results were in agreement with the findings of the earlier analysis. A somewhat surprising result was that even for comparatively deep forcing a non-negligible residual flow evolved for the heating case. This was due to the fact that, a given perturbation in the height of a pressure surface, shallow oscillations will generate larger velocity perturbations than deep oscillations, thus the effect of the shorter scales is enhanced relative to their prevalence.

Our initial modeling effort involved time-dependent calculations of the transient response of the atmosphere to a sudden injection of energy and momentum. A simple linear model indicated that a rapid deformation of pressure surfaces across an initial eastward flow can occur (unless the initial disturbance is very shallow), bringing the flow into geostrophic balance with little reduction in amplitude. However, if the initial flow is very shallow, adjustment takes place slowly, and much of the energy of the initial flow is transferred to inertia-gravity wave. A paper on the subject has been revised and will be published in the Journal of the Atmospheric Sciences. In addition, an invited review paper on the subject of geostrophic adjustment was presented at the Spring Meeting of the American Geophysical Union.

In collaboration with Prof. Karl Taylor of the University of Florida, who is spending the summer working in the laboratory, we have begun development of a sophisticated high-resolution two-dimensional model of the atmospheric response to a geomagnetic substorm. Our goals are to study in detail the dynamical adjustment to time-dependent heat and momentum sources when dissipative and nonlinear effects are taken into account, and to develop



nonreflecting boundary conditions for use in a high-resolution three-dimensional model. (Since a high-resolution three-dimensional model would be prohibitively expensive for a large domain of integration, boundary conditions must be implemented which will prevent fast moving waves generated in the source region from being reflected back into the auroral region during the simulation.) We have formulated the model equations, worked out a numerical scheme, substantially completed coding of a model with homogeneous boundary conditions, and have made some initial runs.

#### F. Auroral Electron Interaction with the Atmosphere

The stated problem was studied with respect to: (a) the high energy (0.5-5 keV) electron precipitation occurring in the discrete auroral arcs of the evening sector, and (b) with respect to the much softer electron (a few tens of eV - 100 eV) precipitation taking place in the cusp region.

Interaction of auroral electrons with the atmosphere produces ionization and excitation of atmospheric species and a significant backscattering of both primary and secondary electrons in the upward direction. Backscattered electrons with  $E < E_b$  are trapped between the lossy ionosphere below and the electric field above, and are reflected back and forth a few times before precipitation into the atmosphere. This important effect was included in our studies of auroral electron interaction with the atmosphere. We used numerical solutions of the multiangle equation of transfer at all energies. Most previous studies of auroral electron-atmosphere interaction employed a hybrid approach which uses Fokker-Planck techniques in the range  $E > 500$  eV and transport equation at lower energies. This approach obviously suffers from the problem of matching the solution at the boundary of the two energy regions. We avoided this problem by solving

the transport equation at all energies. Another serious shortcoming of all previous studies of this problem has been that they considered only two streams, viz., an upward beam and a downward beam. In contrast, we considered sixteen pitch angles, eight corresponding to the upward directions and an equal number in the downward direction. Due to this significant improvement we were able to obtain the pitch angle distribution of the auroral electron throughout the atmosphere. As a result we found that the auroral plasma, including those observed at the satellite and rocket altitudes, has three components: (a) a low energy isotropic component consisting of secondary electrons of atmospheric origin, (b) mostly downward flux which included the auroral primary beam, and (c) a field perpendicular component with energy around the beam energy. The identification of a field perpendicular component constitutes an important outcome of the present study, because the existence of this component can lead to interesting kinetic effects.

Interaction of the softer electrons of the cusp region with the atmosphere presents a more difficult problem with respect to the solution of the transfer equation. The elastic scattering of high energy auroral electrons can be satisfactorily described by the Rutherford cross section. Such is not the case with the low energy cusp electrons. The differential elastic scattering cross sections of low energy electrons ( $E < 200$  eV) tend to have a peak in the backward direction. This becomes quite important at or below 100 eV. The transport code used for the auroral study was therefore modified to take into account this feature in the differential elastic scattering cross sections of low energy electrons. For this purpose, the measured differential elastic scattering cross sections of O, O<sub>2</sub> and N<sub>2</sub> were fitted by a sum of two Rutherford type expressions. The original code used a numerical method to evaluate certain integral over pitch angles. The modified code performed the

same integral analytically. This improvement is quite useful in the study of the cusp region, because the differential elastic scattering cross section of low energy electrons involved two Rutherford type cross sections instead of one. Another special feature of the cusp region is the role of photoelectrons. In our studies of the cusp region, therefore, we examined the fluxes of both photoelectrons and precipitating soft electrons. Depending upon the time of the day (i.e., solar zenith angle) the fluxes of the photoelectrons may completely swamp the fluxes due to the precipitating electrons in the low energy ( $E < 20-30$  eV) region. The photoelectron population, however, diminishes dramatically above 50-60 eV. Observations in this high energy region, therefore, are representative of the precipitating electrons irrespective of the solar zenith angle. At twilight (solar zenith angle  $> 100^\circ$ ), the contribution of the photoelectrons is, of course, negligible.

Currently, at the completion of the above studies, we are directing our attention towards application of the atmospheric interaction code to calculate the emission of auroral X-rays and UV electromagnetic radiation.

### III. DISCUSSION AND OVERVIEW

Research activities reviewed in the previous section and publications listed in Appendix I summarize the execution of our research plan, as envisioned in the original proposal in 1972. In sum, the research team, composed of both senior and junior scientists of several distinct solar-terrestrial disciplines, channeled their activities toward a single goal: understanding of auroral magnetosphere-ionosphere-atmosphere coupling. Included in our research activities are frequent visits and cooperative work with scientists from other institutions.

Since we are at the base-building phase of this long-term goal, our initial researches seem to cover a spectrum of auroral phenomena whose relationships to each other have yet to be fully explored. Such a phase of research activity is unavoidable if our research plan is to be realized. This is especially true since complex computational programs, such as modelling of auroral potential structures, auroral atmospheric dynamics and auroral electron interactions with the atmosphere, must be individually constructed to form the basis for our eventual goal of unification.

Despite the distraction of such necessary preparatory work, the physical content of our basic theme of seeking the origins of auroral magnetosphere-ionosphere-atmosphere coupling in global scale kinetic plasma theory is revealed in our emphasis upon observational verification of our theoretical results. To make this point clear, it is perhaps important to carefully distinguish our approach to auroral physics (global scale kinetic plasma theory) from simulations and other local scale considerations of microphysics in which global scale effects are set up by artificial boundary conditions of

the simulation "box". Our cooperative examination of auroral observations with experimentalists has demonstrated, again and again, that the two approaches are not the same (cf. Chiu et al., 1983a). Global scale auroral plasmas, in its cumulative interactions with global scale inhomogeneous magnetic and electric fields, arrives at the auroral zone with its own boundary conditions which in turn are influenced by the microphysics. Local microscopic interactions, amenable to simulation studies, are but one of the many factors that influence the behavior of the plasma in the auroral zone. Equation (1) is a very good example of this interaction between "boundary conditions" and kinetic plasma characteristics. The parallel electric field has its origins in the perpendicular electric field which in turn is dictated by the global configurations of the magnetosphere. Microscopic plasma interactions merely deals with the distribution of the parallel electric field. Thus, to seek the origin of the discrete arc is to seek the origin of the perpendicular electric configuration favorable to upward field-aligned current, as indicated in Eq. (1). Since simulation studies are (at present) incapable of dealing with these global issues, a research strategy based on the Boltzmann-Maxwell equations must be used to connect the spectrum of scales involved in auroral phenomena. The example of auroral potential structure, cited above to illustrate this principle, is not unique. We find, for example, the same operating principle in SCATHA plasma data which show that global electric and magnetic field structures dictate the plasma kinetic characteristics observed in the auroral equatorial region (Chiu and Kishi, 1983).

The unification of global auroral structure and auroral microphysics is precisely the theme of the next phase of our research plan.

## APPENDIX I: PUBLICATIONS AND PRESENTATIONS

### Papers Published (as of September 30, 1983)

1. Chiu, Y. T. and J. M. Cornwall, Electrostatic model of a quiet auroral arc, J. Geophys. Res., 85, 543, 1980.
2. Chiu, Y. T., J. M. Cornwall and M. Schulz, Effects of Auroral-particle anisotropies and mirror forces on high-latitude electric fields, Physics of Auroral Arc Formation, AGU Monograph Vol. 25, pp. 234-244, 1981.
3. Chiu, Y. T., A. L. Newman and J. M. Cornwall, On the structure and mapping of auroral electrostatic potentials, J. Geophys. Res., 86, 10029-10037, 1981.
4. Schulz, M., Y. T. Chiu and J. M. Cornwall, Theory of the auroral magnetosphere, Proceedings of the Finnish-American Auroral Workshop, Oulu, Finland, 1981.
5. Cornwall, J. M. and Y. T. Chiu, Ion distribution effects of turbulence on a kinetic auroral arc model, J. Geophys. Res., 87, 1517-1527, 1982.
6. Kan, J. R., L. C. Lee, Y. T. Chiu and D. U. Longenecker, Generation of Alfvén waves by deceleration of magnetospheric convection and broadband PI pulsations, J. Geophys. Res., 87, 3511-3518, 1982.
7. Walterscheid, R. L., The semiannual oscillation in the thermosphere as a conduction mode, J. Geophys. Res., 87, 3511-3518, 1982.
8. Prasad, S. S., D. J. Strickland and Y. T. Chiu, Auroral electron interaction with the atmosphere in the presence of conjugate field-aligned electrostatic potentials, J. Geophys. Res., 88, 4123-4130, 1983.

9. Chiu, Y. T., J. M. Cornwall, J. F. Fennell, D. J. Gorney and P. F. Mizera, Auroral plasmas in the evening sector: Satellite observations and theoretical interpretations, Space Sci. Revs., 35, 211-257, 1983a.
10. Cornwall, J. M., The connection between radiation belt and auroral processes, Space Sci. Revs., 34, 235-243, 1983.
11. Chiu, Y. T., M. Schulz, J. F. Fennell and A. M. Kishi, Mirror instability and the origin of morningside auroral structure, J. Geophys. Res., 88, 4041-4054, 1983b.
12. Chiu, Y. T. and D. J. Gorney, Eddy intrusion of hot plasma into the polar cap and formation of polar-cap arcs, Geophys. Res. Lett., 10, 463-466, 1983.

Papers Accepted (as of September 30, 1983)

1. Walterscheid, R. L. and D. J. Boucher, A simple model of the transient response of the thermosphere to impulsive forcing, J. Atmos. Sci., 1983.

Papers Submitted (as of September 30, 1983)

1. Chiu, Y. T., and A. M. Kishi, Kinetic model of auroral plasma formation by magnetospheric convection and injection, I. Electrons, J. Geophys. Res., 1983.

Papers in Preparation (as of September 30, 1983)

1. Newman, A. L., Y. T. Chiu and J. M. Cornwall, Two-dimensional model of auroral potential structure, J. Geophys. Res., 1984.

2. Chiu, Y. T., N. U. Crooker and D. J. Gorney, Polar cap arc formation, J. Geophys. Res., 1984.
3. Prasad, S. S. and Y. T. Chiu, Dayside auroral electron interaction with the atmosphere, J. Geophys. Res., 1984.

Invited Presentations (as of September 30, 1983)

1. Chiu, Y. T., A. L. Newman and J. M. Cornwall, On the structure and mapping of auroral electrostatic potentials, AGU 1981 spring meeting, Baltimore, MD.
2. Schulz, M., Y. T. Chiu and J. M. Cornwall, Theory of the auroral magnetosphere, Auroral Workshop, August 1981, Oulu, Finland.
3. Chiu, Y. T., M. Schulz and A. M. Kishi, A theory of morningside auroras, AGU 1981 fall meeting, San Francisco, CA.
4. Cornwall, J. M., Radiation belts and the aurora, 1982 Solar-Terrestrial Physics Symposium, Ottawa, Canada.
5. Chiu, Y. T., J. M. Cornwall and M. Schulz, The kinetic state of auroral plasmas, 1982 Solar-Terrestrial Theory Conference, Boston, MA.
6. Walterscheid, R. L., Mechanistic models of thermospheric dynamics, American Geophysical Union, Baltimore, MD, 1983.
7. Schulz, M., The partially open magnetosphere, American Geophysical Union, Philadelphia, PA, 1982.
8. Chiu, Y. T., N. U. Crooker and D. J. Gorney, Formation of polar cap arcs, Workshop on Polar Cap Processes, AFGL, Bedford MA, 1983.
9. Chiu, Y. T., Origin of the terrestrial aurora, American Geophysical Union, San Francisco, CA, 1983.



10. Chiu, Y. T., Origin of the auroral potential structure, COSPAR Symposium on Collisionless Shocks and Particle Acceleration Processes, Graz, Austria, 1984.
11. Gorney, D. J., Potential structures and particle acceleration on auroral field lines, COSPAR Symposium on Collisionless Shocks and Particle Acceleration Processes, Graz, Austria, 1984.

Contributed Presentations (as of September 30, 1983)

1. Walterscheid, R. L., The semiannual oscillation in the thermosphere as a conduction mode, Fourth IAGA 1981 Scientific Assembly, Edinburgh, Scotland.
2. Newman, A. L., Y. T. Chiu and J. M. Cornwall, Theoretical modelling of auroral electrostatic potential structures, AGU 1981 fall meeting, San Francisco, CA.
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